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Insight into the applications of palm oil mill effluent: A renewable utilization of the industrial agricultural waste

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ABSTRACT

Water scarcity and pollution rank equal to climate change as the most intricate environmental turmoil for the 21st century. Today, the percolation of palm oil mill effluents into the waterways and ecosystems, remain a fastidious concern towards the public health and food chain interference. With the innovation of palm oil residue into a high valuable end commodity, there has been a steadily growing interest in this research field. Confirming the assertion, this paper presents a state of art review of palm oil mill effluent industry, its fundamental characteristics and environmental implications. Moreover, the key advance of its implementations, major challenges together with the future expectation are summarized and discussed. Conclusively, the expanding of palm oil mill effluent in numerous field of application represents a plausible and powerful circumstance, for accruing the worldwide environmental benefit and shaping the national economy.

Contents

1. Introduction

Lifeblood for billions of people, oil palm industry has been one of the most successful stories of the world agricultural sector abroad the nations. From a humble source of the edible oil, today oil palm has demonstrated a wide spectrum of implications, almost every part of its plant. Concomitantly blessed with plentiful abundant natural resources and a climate conducive to commercial cultivation of crops, located in the wet and humid tropics, in bands of land extending 10° to the north and also to the south of the Equator [1], with a fair amount of sunshine, hot climate coupled with temperature averages of 25 °C, and high rainfall rate (2.000 mm of rain) well distributed throughout the year [2], Malaysia poses an ideal and substantial potential for the dense tropical forest growth and agricultural vegetation.

During the late 1950s, the expansion of palm oil industry started as part of the government's diversified cautious policy from rubber to oil palm, in alternating the high consumption of crude petroleum oil and raising the socio-economic status of the population in the country [3]. To date, its growth has been phenomenal in Malaysia, replacing Nigeria as the chief producer since 1971 [4]. Maintaining the top seat as the largest supplier, the annual oil production figures in 2000 and 2008 were individually recorded at 8.3 and 16.3 million tonnes, underlying the steep enrichment of the giant processing industries and sophisticated technologies as its key drivers [5]. Simultaneously, from merely 54,000 ha in the early 1960s, the oil palm plantation area has gradually increased to 1.8, 3.5, 3.8, 4.2 and 4.3 million hectares in 1990, 2001, 2003, 2005 and 2007, representing 56% of the total agricultural land and 11.75% of the country's total land area [6],

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managed by the publicly listed companies, smaller independent estates, independent smaller holders and government smallholder settler schemes around the Peninsular Malaysia and the east states of Sabah and Sarawak [7].

For each tonne of crude palm oil produced from the fresh fruit bunches, approximately 6 tonnes of waste palm fronds, 5 tonnes of empty fruit bunches, 1 tonne of palm trunks, 1 tonne of press fibre (from the mesocarp), 500 kg of palm kernel endocarp, 250 kg of palm kernel press cake, and 100 tonnes of palm oil mill effluent (POME) can be obtained [8]. By nature, fresh palm oil mill effluent is an acidic, thick, brownish, viscous and voluminous colloidal suspension with 95–96% of water, 0.6–0.7% of oil and 2–4% suspended solids [9], originating from the mixed stream of sterilizer condensate, separator sludge and hydrocyclone wastewater, chiefly in the form of mesocarp fibres (press cake fibre), empty fruit bunches and stalk materials after fruit stripping [10].

Containing an essential amount of amino acids, inorganic nutrients (sodium, potassium, calcium, magnesium, manganese, and iron), organelles, short fibres, nitrogenous constituents, free organic acids and an assembly carbohydrates ranging from hemicellulose to simple sugars [11], it is featured by low pH value of 3.5–4.5, high biological oxygen demand of 10,250–43,750 mg/L, chemical oxygen demand of 16,000–100,000 mg/L, suspended solids of 5000–54,000 mg/L, nitrogen content ranging from 200 to 500 mg/L as ammonia nitrogen and total nitrogen and discharge temperature of 80–90 °C [12]. In the early irrigation, it was a common practice to dispose oil palm refuse by uncontrolled tipping or dumping, an operation in which waste is spread over the estates ground or tipped to fill in low economic value open dumps on selected pieces of land (inundated swampland, abandoned sand mines and quarries), without taking care of the surrounding environment, nor considering any precautions to compact, cover and prohibit the percolation of contaminants into the underlying waterways.

Lately, the enforcement of environmental rules and regulations concerning the monitoring of pollution from palm oil mill effluent waste streams by regulatory agencies are becoming more stringent and restrictive, inevitably affect the design, planning, and operation of the palm oil milling industry. Numerous mitigating tactics and imperative technologies have drastically been addressed and confronted (adsorption [13], solvent extraction [14], chemical–biological sedimentation [15], coagulation–flocculation [16] and membrane technologies [17]). Of major interest, biological treatment [facultative lagoons, open tank digester, ponds aeration, anaerobic baffled (ABR) and upflow anaerobic sludge blanket (UASB)] is recognized as the most common and desirable management strategy for sustainable disposal and elimination of palm oil residue wastes, both in fully industrialized and developing countries [18], in terms of its simplicity, low energy demand, moderate capital costs, and high organic loadings capability [19].

Despite its prolific use for removal of a broad types of organic and inorganic pollutants dissolved in aqueous media, such exertions are hampered by the constraints of its long hydraulic retention time (often in excess of 20 days), necessity of large digesters and plant size, sensitivity of microorganisms to the environmental alteration, and vast emission of corrosive and odorous biogas (methane, carbon dioxide and trace amounts of hydrogen sulfide) [20,21]. This has inspired a growing research interest in establishing a leading selective, reliable and durable alternative for judicious utilization of the heavily polluted palm oil mill effluents [22]. With the aforementioned, this bibliographic review attempts to postulate an initial platform in describing the distinct physiochemical properties, development and potential applications of the palm oil mill effluent industry. The present work is aimed at providing a concise and up to date picture of the present status of the oil palm waste enhancing sustainable and renewable energy. The prospects towards utilization of palm oil mill effluent as renewable sources together with its comprehensive literature has been highlighted and outlined, to familiarize the knowledge deficiencies regarding oil palm industry.

2. Utilization of palm oil mill effluent for hydrogen production

Over the past several decades, the exponential population and social civilization expansion, changes affluent lifestyles and resources use, and continuing progress of the industrial and technologies has been accompanied by a sharp modernization and metropolitan growth. Hitherto, the ever-increased importance of the biomass as renewable energy resources has been accounted by the rising demand and rapid depletion of the exhaustible fossil fuels [23–25]. With the price of the crude petroleum oil escalating to an unprecedented height every other day due to political instabilities in many oil-exporting countries and dwindling oil reserves in the world, the quest for an alternative energy which is affordable and environment-friendly is inevitable [26,27].

In particular, the departure of the concept of generating energy from bio-hydrogen gas, exclusively derived from electrolysis of water, steam reformation of methane, thermo-catalytic reformation of organic compounds and biological processes (via light driven photosynthesis and chemosynthetic fermentation), has received stern encourages and considerations worldwide [28,29]. Ample ancient historical documents, the pioneering works regarding isolation of natural microflora from palm oil mill effluents was firstly proposed by Morimoto et al. [30] in 2004, suggesting the evolution of bio-hydrogen after an acclimatization period of 20 h at 60 °C. In the attendance of acidogens at higher temperature and lower pH value, a substantial formation of acetate and butyrate acids were illustrated, ascribed to the hindering effect and deactivation of methanogenic phase in the anaerobic digestion system.

Ten months later, similar research has been advanced by Atif et al. [29] by inoculation of culture medium comprising 4.5 L palm oil mill effluent with 2.5% sludge (w/v) in a fermentor at 60 °C, pH 5.5, and constant mixing at 200 rpm, accomplishing a total yield of 4708 mL H_2/L with peak evolution rate of 454 mL H_2/L h. The extent of effort has promulgated for the next 5 years, and today, a variety of scientific publications and manifestations covering the hemoheterotrophic chemistry have been executed tremendously (Table 1). In most cases, the complimentary technique was

Table 1
Previous researches in the utilizing palm oil mill effluent for the production of hydrogen biofuel.

Maximum hydrogen generation (mL/L)	Production rate (mL/L h)	Hydrogen content (%)	Maximum COD removal (%)	Optimum pH	Reference
3.195	1.034	62	–	5.5	[28]
4.708	454	66	–	5.5	[29]
534	64	–	–	–	[30]
1.210	251	58	–	5.5	[31]
6.710	34	–	63	–	[32]
–	543	–	–	6.25	[33]
102.6	–	57	67	5	[34]

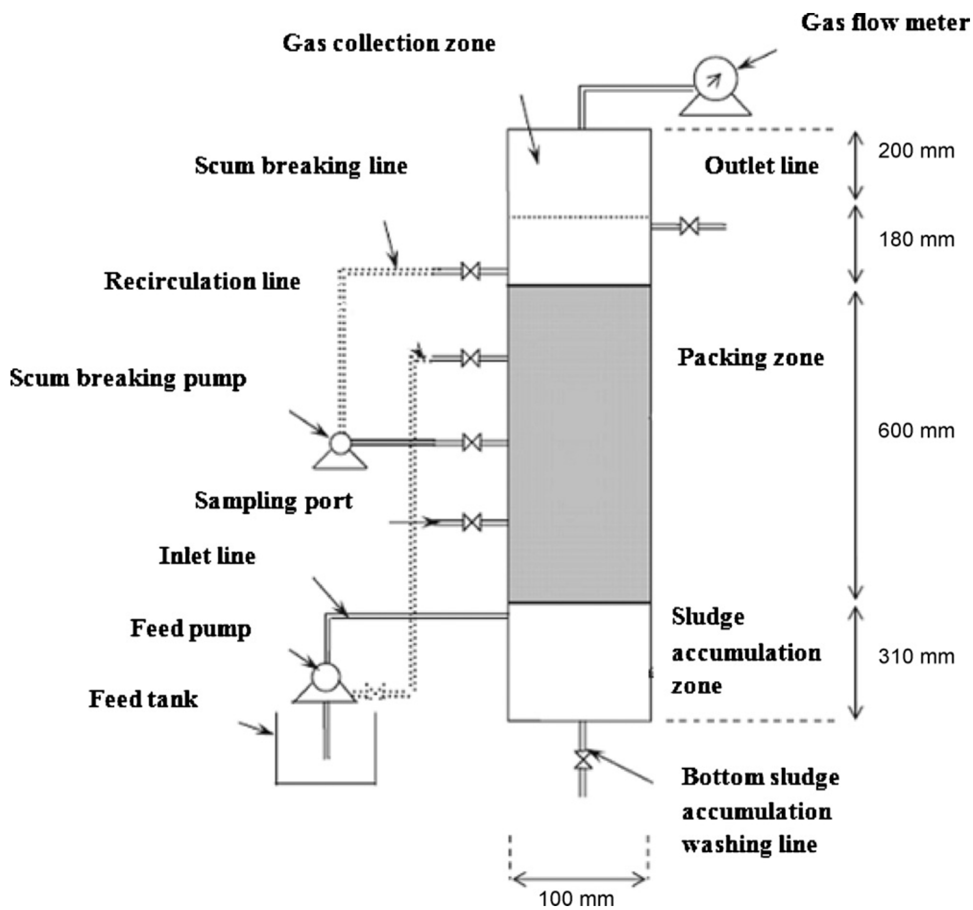

Fig. 1. Schematic diagram of upflow anaerobic contact filter for biohydrogen generation [34].

reported remarkably depresses the dependence on fossil fuel, pollutants emissions and capital cost (estimation cost 340 times lower than photosynthetic process [35]), while enhances the higher reaction rate (operating without light sources and oxygen limitations), hydrogen production capacities and energy recovery, thus directing a bearing for overcoming the local trans-boundary pollutants (acid rain and green house gases) and environmental quality conservation [36].

In 2006, the early study conveying the idea adopting palm oil mill effluent as supplementary substrate in the anaerobic contact filter system (under mesophilic conditions) has been advocated by Vijayaraghavan and Ahmad [34] (Fig. 1), signifying a cumulative biogas generation of 11.8 L/week (56% hydrogen) corresponding to chemical oxygen demand (COD) removal of 67%. Relatively, O-Thong et al. [32,33] have assessed tentative emphases for specific detection of the spatial distribution of hydrogen producing bacteria and optimization of the thermophilic fementative system, denoting a hydrogen production of 6.51 H_2/L couple with a COD discrimination of 58% (Fig. 2). Upon the dark fermentative transformation, hydration of glucose molecule elucidates a concurrent generation of hydrogen and acetic acids in the ratio of 2:1 (Eq. (1)), which for favorable conversion of butyric acids, the portion of hydrogen produced is reduced proportionally (Eq. (2)).

$$C_6H_{12}O_6 + 2H_2O \rightarrow 2CH_3COOH + 2CO_2 + 4H_2 \quad (1)$$

$$C_6H_{12}O_6 \rightarrow CH_3CH_2CH_2COOH + 2CO_2 + 2H_2 \quad (2)$$

In this respect, O-Thong et al. [37] has performed a microscopic and phenotypic test for identification of the thermophilic fermentative bacterium from a continuous sequencing batch reactor digesting palm oil mill effluents. Result anticipated the presence of *Thermoanaerobacterium thermosaccharolyticum* PSU-2 (Fig. 3), a rounded ends and spore forming gram-positive cell, with a length of 0.3–2.3 mm, usually exists singly or in pairs (rarely in chains). pH reduction facilitates the accumulation of acidic metabolites, which destabilizes its ability in manipulating the internal pH, thereby resulting in lowering of intracellular adenosine triphosphate (ATP) level (requirement of coenzyme A and phosphate pools for sustaining neutrality) and inhibition of the substrate uptake rate.

Regardless of the concentration changes and vary depending on a complex set of interrelated factors, incorporation of organic nitrogen amendment medium noticeable induced a complete shift to the cell metabolism patent with additional reducing power generation, while a marginal rise of the temperature greater than 60 °C accelerated a significant protein deactivation [38]. The empirical route mechanism associated with ethanol formation during the anaerobic acidogenesis is defined in Eq. (3).

$$C_6H_{12}O_6 + H_2O \rightarrow 2H_2 + 2CO_2 + C_2H_4O_2 + C_2H_6O \quad (3)$$

In Thailand, a comparative evaluation investigating acid, base, 2-bromoethanesulfonic acid, load-shock and heat-shock treatment towards the microbial community structure of the hydrogen production seeds has been undertaken by O-Thong et al. [31]. Volatile fatty acid (VFA) analysis revealed high concentration of acetic acid and butyric acid, while propionic acid, lactic acid and alcohol were present in a minor quantity, implying the domination of the acid-forming metabolic pathway. Load-shock modification at pH control 5.5 devoted the highest hydrogen yield of 1.96 mol H_2 mol^{-1} hexose, with no methanogenic activity detection even with operation term longer than 60 days.

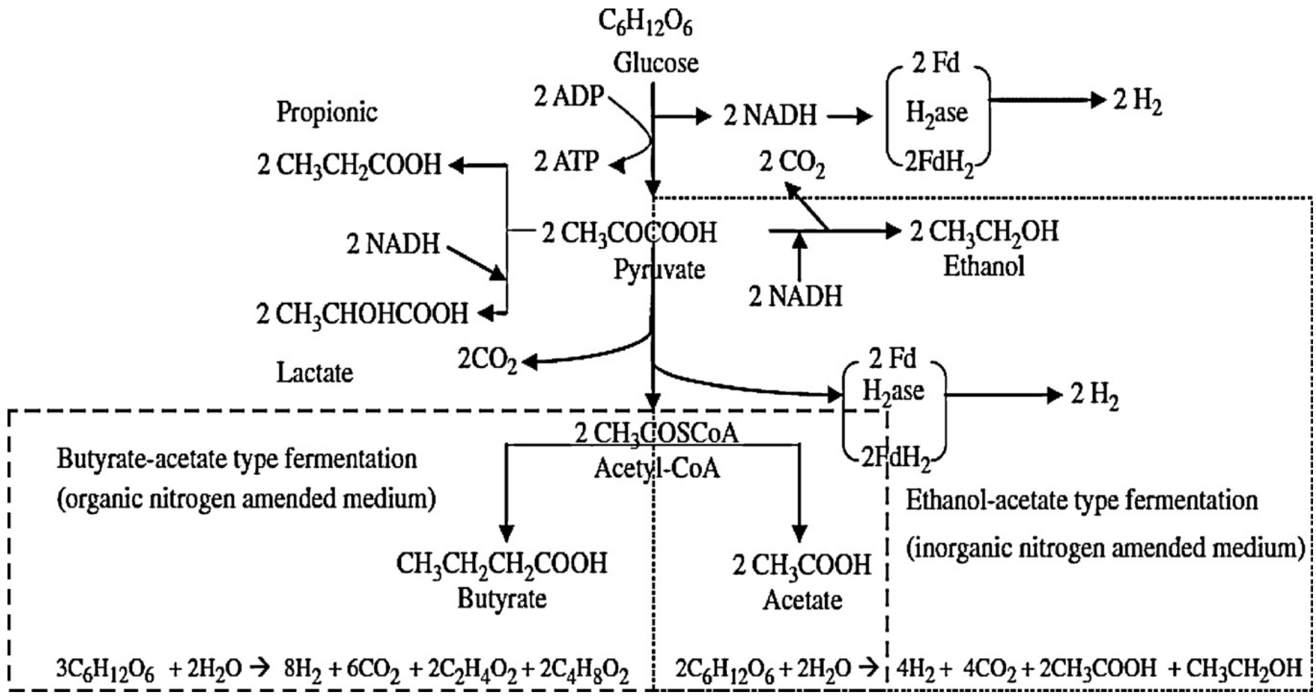

Fig. 2. Suggested metabolic pathway for thermophilic fementative process under organic nitrogen added medium and organic nitrogen deficient medium [33].

3. Prevalence of palm oil mill effluent in the microbiological chemistry

Within the last few years, intensive wide spread contamination of atmosphere and surface water related to adverse industrial operations has intensified an aesthetic concern for many environmentalists [39]. Recently, the infiltration of palm oil mill effluent into the groundwater tables and aquifer systems which constitutes an accumulative, threatening and detrimental deteriorations to the survival of aquatic life form, ecology and food chains, is interpreted as one of the most intransigent paradoxes around the world [40]. In view of the matter, the revolution of palm oil mill effluent in the microbiological science has attracted a huge energetic focus, mainly attributed to its abundantly accessibility and low profitable commercial value.

As early as 1996, the first attempt utilizing palm oil mill effluent for the manufacturing of polyhydroxy-alkanoate, a biopolymer accumulates intracellularly by various bacteria as reserve carbon stores under nutrient limiting conditions, has been conducted by Hassan et al. [41] in a two stage process (Fig. 4). Optimum cell growth (*Rhodobacter sphaeroides*) was attained at pH 7 with mild agitation and intermittent aeration, pre-supported the retarding effect of formic acid formation towards the generation of polyhydroxy-alkanoate and bacterium growth rate. Subsequently, Razak et al. [42,43] have endeavored to extract lipolytic microbes *Rhizopus oryzue* and *Rhizopus rhizopodiformis* from palm oil mill effluent for the production of lipases, a natural immobilized enzyme which poses huge potentiality in the interesterification, ester synthesis and hydrolyses processes, primarily hinges on its shorter generation time, ease of bulk production and manipulation, designated the highest yield at 45 °C and pH 6.0.

In the sugar processing industry, Prasertsan and Oi [44] has examined the influence of temperature and solvent ratio on hemicelluloses isolation for enzymatic saccharification, complying an optimum production of 68% at 121 °C and extraction ratio of 1:50 (w/v). Likewise, Jamal et al. [45] has expressed the possibility of employing palm oil mill effluents as new substrates in the citric acid (lime juice isolated through fermentation process which finds

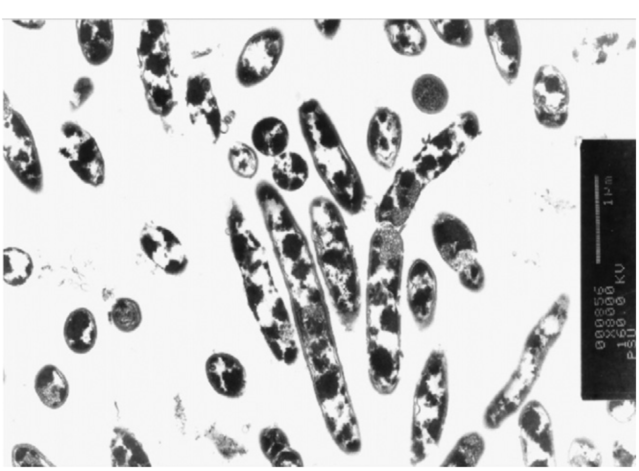

Fig. 3. Transmission electron micrograph of thermoanaerobacterium *thermosaccharolyticum* PSU-2 [37].

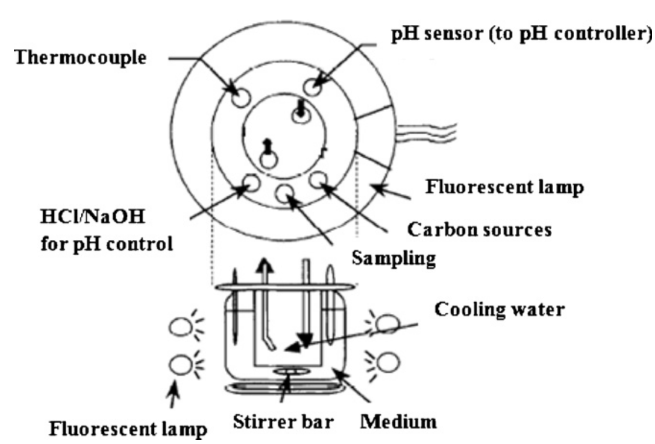

Fig. 4. Schematic diagram of the photobioreactor for manufacturing of polyhydroxy-alkanoate [41].

Table 2
List of filamentous fungi isolated from palm oil mill effluent compost for domestic wastewater sludge bioconversion [49].

Code number	Macro–microscopic characteristics	Identification
PC-A301	Olive to rusty yellow color exhibited mostly compact mycelia/spores mat in potato dextrose agar (PDA) plate. Central part turned to rusty at older ages. Peripheral mycelium was hyaline to light olive color. Conidial cells developed on conidiogenous cell were observed on supporting cells of vesicle. The length of conidiophores was observed intermediate	*Aspergillus* sp.
PC-P302	Slow-growing fungus (0.16% radial growth rate h^{-1}) observed color was confusing as intermediate between blue and green. Slightly dark color was observed in malt extract agar (MEA) than the PDA. The young peripheral edge was white, which was too narrow line in MEA. Folded scars of mycelium mat developed along the radius. In microscopic studies, branched conidiophores produced moniliform conidial chain on conidiogenous cell	*Penicillium* sp.
PC-P303	Slow-growing (0.12% radial growth rate h^{-1}) compact olive colored fungal mat developed in PDA. Narrow slightly white serrated edge was also observed at periphery. Compact bundle of conidial cells developed at ambiguous apex of intermediate length conidiophores	*Penicillium* sp.
PC-P304	Slow-growing fungus (0.15% radial growth rate h^{-1}) exhibited 3.0 cm diameter round mycelia mass in 10 days PDA culture. Smooth cottony hyaline to white narrow peripheral edge was observed. Compact chain of globose conidia was grown on erect divariately branched conidiophores	*Penicillium* sp.
PC-A305	Slow-growing olive to dark green colored compact mycelia mat observed in a PDA. Light chocolate color was also developed at lower side of the plate. Light pale white color line was marked at the edge of periphery. Globose/subglobose conidia were observed in cluster on vesicle of intermediate length of conidiophores	*Aspergillus* sp.
PC-A306	Pale olive to whitish green colored non-smooth cottony mycelia mat (marked with some rusty dots) was observed in PDA media. The edge of periphery grew unevenly with a broad cream to white hairy line. The comparatively shorter length conidiophores produced conidia in compact on swollen apex	*Aspergillus* sp.

wide applications for food and beverages, pharmaceuticals, cosmetics and household detergents products) screening test.

4. Recycling of palm oil mill effluent as renewable sources of fertilizers and carotene

Of late, the versatility of recycling and reservation of agricultural waste as renewable resources has been one of the most challenging tasks, which is deeply embedded with extensive momentum and popularity. In line with the projected growth of the palm milling industries, the annual palm oil mill effluent production rate was estimated at 27 million m^3/year [46]. In the perspective, Chulan [47] has initialed a greenhouse experiment to investigate the effect of vesicular–arbuscular mycorrhiza towards the growth and nutrient uptake rate of *Theobroma cacao* L., a cocoa seedling treated with palm oil mill effluent, in an unsterilized Oxisol and Utisol. Under proper agronomic practice, palm oil mill effluent reacts as a unique nutrient source, which contributes directly to the decomposition of soluble phosphate (or insoluble organic phosphate) and improving of physical and microbial soil sanitation, leading to a tremendous elevation of crops yield.

Dry matter yield increased quantitatively with the addition of palm oil mill effluent, computing a competent phosphorus recovery of 24.8% (quadratic relationship). Exploration in symbiosis relationship offers a viable substitution to the excessive application of chemical fertilizers, thus alleviating the severe economic constraint of fertilizer input, quoted a cost saving of \$5.00 ha^{-1} of plantation.

In the latter case, Onyia et al. [48] has assigned palm oil mill effluent-nitrifiers mixed culture as an effective tool for bioaugmentation, an application which indigenous or allochthonous organisms are abounded to stimulate the removal of polluted hazardous waste and undesired compounds for enhancing nitrification processes. Full nitrification was completed in a 7 days inoculation period, at 30 °C, pH 7.5, with 2N sterile sodium hydroxide, illustrating a 60% deduction in hydraulic retention time. Accordingly, Molla et al. [49] has exhibited the prominent role of palm oil mill effluent in composting process, a bioconversion of organic substrate into a stable end product (compost) for preserving the soil fertility (Table 2). Arising with the heavily inventions in the health science and dietitian research, lately, Ahmad et al. [50] has exploited a new discovery in the oil palm processing industries by recovery of carotenes, the most important vitamin A precursor in the nutrition chemistry, which protects against night blindness, skin disorders, toxins, colds, flu infections and strengthening of immunity level. Optimum extraction ratio was assessed at 0.6 (solvent/POME), imposing a peak recovery of 71.1%.

5. Emergence of palm oil mill effluent in the biofuel processing industries

Stepping into the new globalizes and paradigm shifted era, biodiesel industry, manufactured by the esterification of renewable oils, fats and fatty acids has emerged to be a novel growing branch in fulfilling the pressing need for renewable energy and diminishing reserves of the world fossil fuel [51–56]. Unfortunately, in terms of its sustainability, the conversion of biodiesel is currently encountering extensive perplexities associated with disproportion amount of impurities, limitation of yield, food versus fuel dispute and solid residues generation [57]. Realizing the constrictions, in 2003, Shirai et al. [7] has alleged the prevalence of palm oil mill effluents as a holistic approach in creating an eco-friendly energy feedstock input (Fig. 5).

On the basis of a relative composition of 65% methane and 35% carbon dioxide (in the case of open digesting tank system), preliminary study has reflected an average emission of 32–48 kg of methane/ha year, which in a time horizon of 100 years, 1 kg of methane release is corresponding to 24.5 kg of carbon dioxide, thus diverting towards the dramatic greenhouse phenomenon [58]. Coinciding in ratifying the United Nations Framework Convention on Climate Change (UNFCCC) and the clean development mechanism (CDM) under the Kyoto Protocol [59], recently, cogeneration of methane gas from the palm oil mill effluent, an abundant, untapped

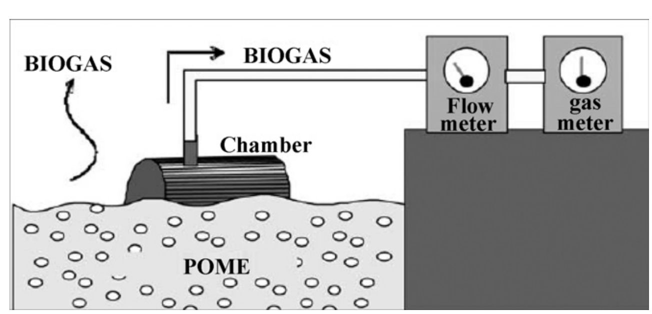

Fig. 5. Equipment setup for generating methane gas from palm oil mill effluents [7].

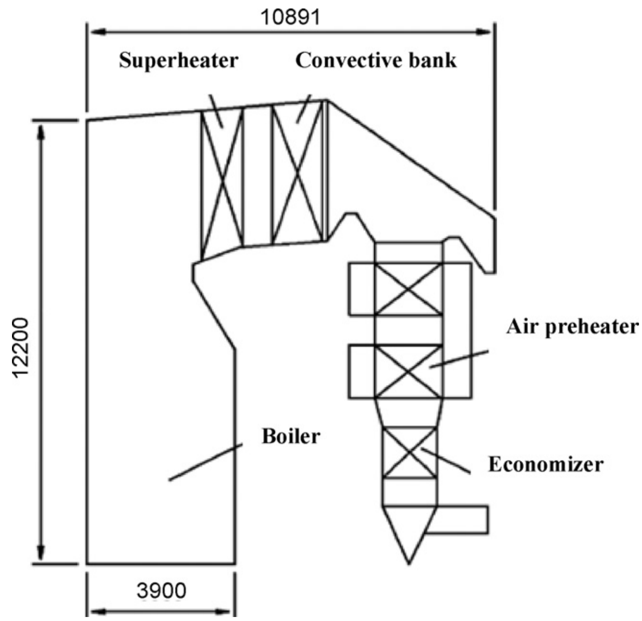

Fig. 6. Scheme of the proposed boiler utilized in the methane gas cogeneration power station [60].

and environmentally friendly fuel with a calorific value of 34.5 MJ m^{-3}, has appear to be a thermodynamically interesting, technically compromise and economically attractive technique by promoting a number of advantages including higher reaction rate, better process performance, improved solids dewatering and effective removal of pathogens [60].

Financial analysis (based on a life-cycle cost-benefit model) elucidated annual revenue of 31–58%, and payback period of 1.5–2.5 years, validated its implementation for electricity generation and heat recovery [46]. Arrieta et al. [60] in a separated study verified that with specific investment costs of 690–850 US$ kW^{-1} (according to the capacity), electricity tariff and the price of commercialization of the surplus electricity ought to be ranged between USD$ 0.11 and USD$ 0.16 kWh^{-1} (Fig. 6). Parallel to the Fifth Fuel Policy and Small Renewable Energy Programme (SREP), endorsed by the Ministry of Energy, Communications and Multimedia Malaysia, specific economic incentives were launched to the primer energy producers, Tenaga Nasional Limited Company (the Peninsular), Sarawak Electricity Supply Corporation (Sarawak State), and Sabah Electricity Board (Sabah State), predominantly for small electricity generation plants (less than 10 MW capacities) which formulated palm oil mill effluent as a base towards the energy recovery [46].

In the same vein, two clean development mechanism (CDM) projects hosted by the Kim Loong Power Private Limited (Project, 0867) and United Plantations Limited companies (Project, 1153) have been registered for regulating methane gas from palm oil mill effluent anaerobic bioreactors [61], while Bumibiopower, a 1–1.5 MW renewable energy power plant developer under Mitsubishi Securities Corporation Limited company, is in the progress of plant installation for methane extraction [23]. On the contrary, Hipolito et al. [62] has indicated the suitability of palm oil mill effluents as medium substitute and efficient source of nitrogen or micronutrients in the acetone buthanol–ethanol fermentation process (by *Clostridium saccharoperbutylacetonicum* N1-4). pH 5.8 was evidence to be the best operating condition, while collaboration of redox dye, an artificial electron carrier for mediation of natural electron transfers has successfully distributed the NADH/NADt ratio (or electron flow) and therefore modified the metabolism (of the microorganism) by dictating the direction of carbon flow towards alcohol formation in the solventogenic clostridia, uplifted buthanol production as much as 4.8 g L^{-1}.

6. Major challenges and future prospects

The world is currently facing the worst environmental crisis in its entire history. For the past two decades, diversification of huge waste production and environmental preservation has focused critical attention towards the recycling and reservation of agricultural biomass resources. With the vital development of the biofuel markets in the European Union and growing food demand in Indonesia, India and China [63–69], the world palm oil production is forecasted at an annual increscent of 9%, which in Malaysia alone, more than 2.8 million hectares of land is under oil palm cultivation, translating to around 27 million m^3 of palm oil mill effluent [46].

In step towards achieving the status of green environmental policy and cleaner technology approach, the innovation of palm oil mill effluent in a broad variety of applications (hydrogen production, microbiological chemistry, renewable sources of fertilizers and carotene, and biofuel processing industries) has seen a panacea and new menu to reconcile agriculture practices, for insuring long-term agricultural operations and sustainability of the cropping systems. Fluctuating upon the alterations of time, place and context, environmental effectiveness, technological feasibility, social acceptability and economical affordability are usually the key factors deciding its flexibility, reliability and sustainable manner. Although there has been some successful industrial-scale production of renewable resources from palm oil mill effluent, generally the industry is still facing various challenges, the availability of economically viable technology, sophisticated, natural resources management, and proper market strategies under competitive markets.

Amidst these challenges, the urgency of conceiving and administrating the strategic, corrective and transparent policies, mandates and standards ministering various contaminants from agricultural waste streams need to be properly legislated and well-planned. Increasingly, the sound professional knowledge of creating environmental awareness for adequate engineering and operating standards, responsibilities sharing, public participation, and regular opinion survey ought to be properly pointed out and counteracted. In Malaysia, the enactment of the Environmental Quality Act of 1974 and the subsequent reinforcement of the Department of Environment in 1976 was empowered in 1985 to include the submission of Environmental Impact Assessment (EIA) reports on proposed development program to the Department of Environment (DOE) for approval [70]. Ultimately, full co-operation and joint venture between different parties (nations, states, local government, private sector and communities) from upstream till the bottom line with compatible technologies is a promising sign for the race to the end line.

7. Conclusion

Over the years, the world's accessibility oil reserves are gradually depleting, riding towards the overwhelming researches dealing with agricultural waste utilization. Predictions for the next 20 years indicate an ascending impact in the agricultural waste production and, subsequently in palm oil mill effluent generation. Today, the growing discrepancy and limited success of remediation in field applications has raised apprehensions over the use of palm oil mill effluent as a measure to the environmental pollution control. The evolution has turned from an interesting alternative approach into a powerful standard technique by offering a numbers of advantages. Although it is still in the infancy, a widespread and great progress of in this area can be expected in the future.

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